EIC R&D Meeting. July 26, CUA

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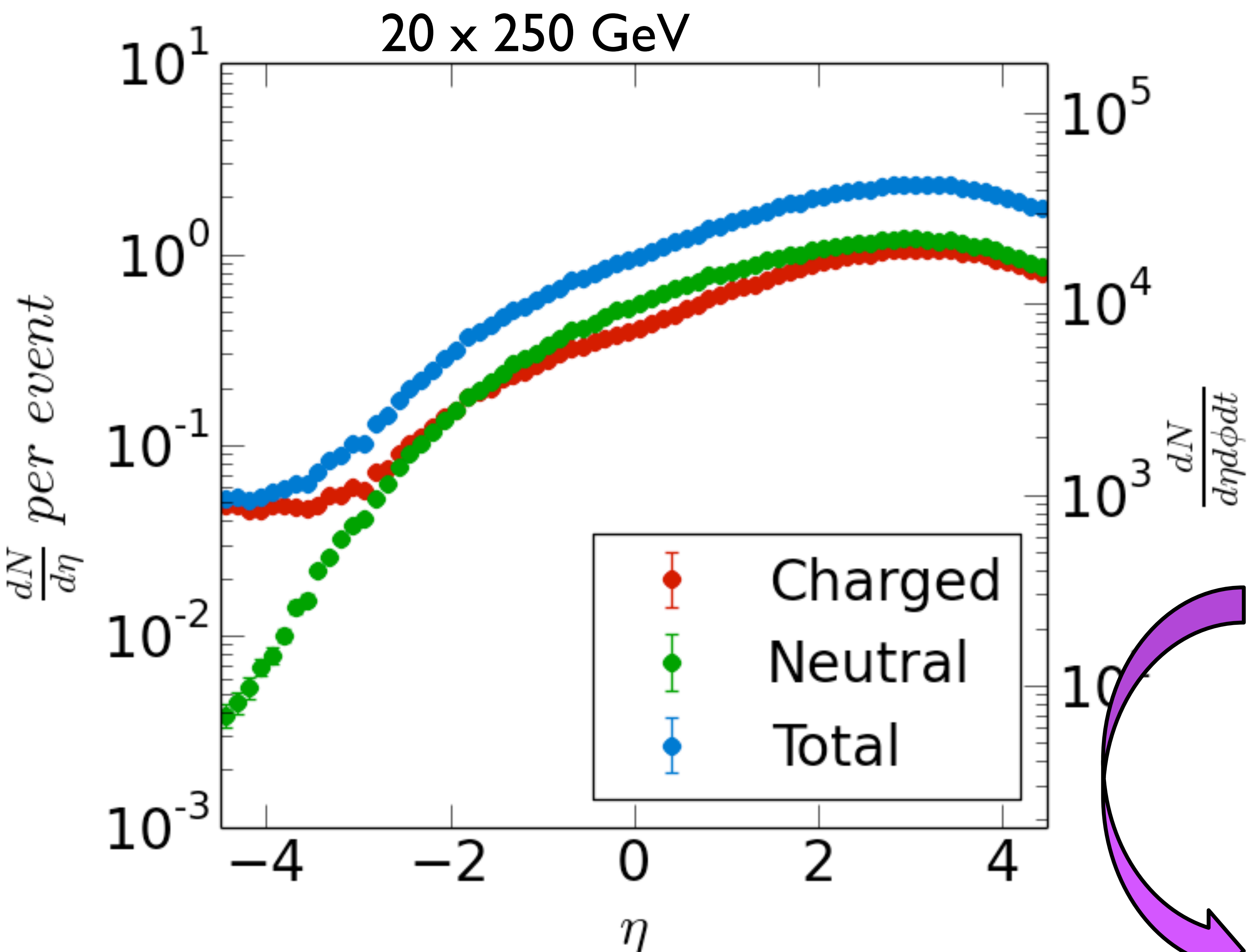
FY19 topics

- **Test alternative scheme of readout for Barrel W/ScFi Emcal.**
- **Test of dual readout concept 'time development of hadronic showers' toward high resolution hadron calorimetry at EIC.**

Key Words: occupancy, rates, energy resolution, radiation damages, light collection, practical considerations.



https://wiki.bnl.gov/eic/index.php/Detector_Design_Requirements

eRHIC L $=10^{33}$ $cm^{-2}s^{-1}$

Conditions in Central Detector:

- Low multiplicity.
- Low Rates.

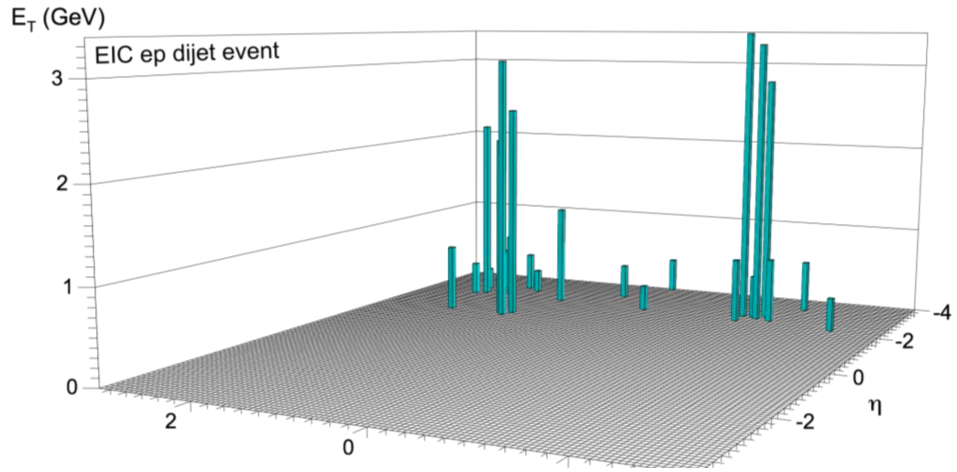
Detector Parameters:

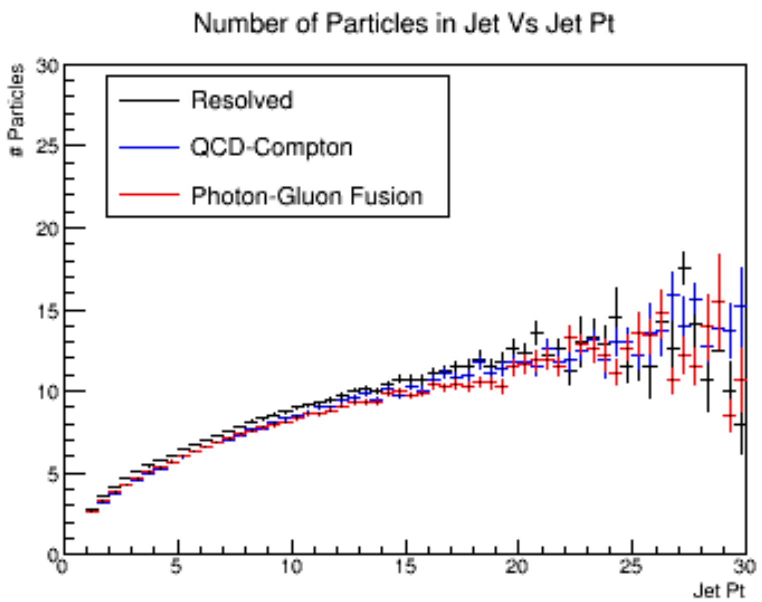
- EMCal, granularity.
- HCal, signal integration over large detector volume.
- Hcal, signal inegration over long time.

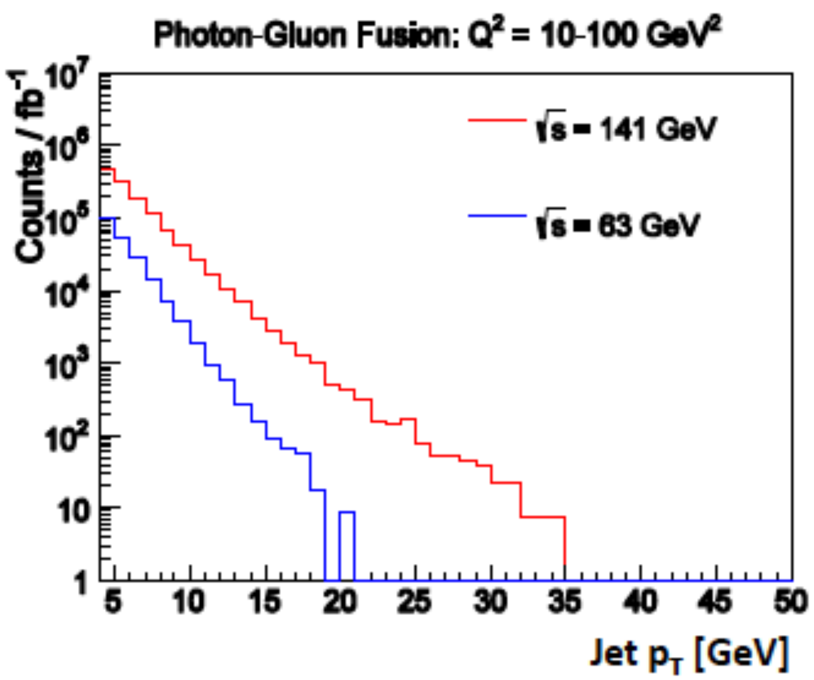
Techniques for High Resolution HCals:

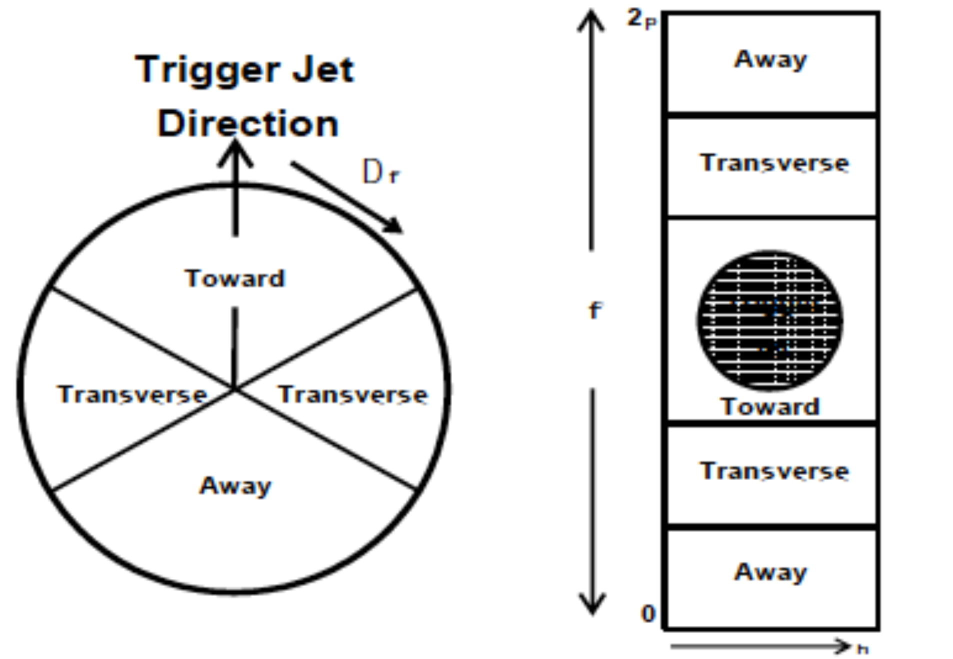
- Compensation (2014).
- Dual Readout using timing (2018).

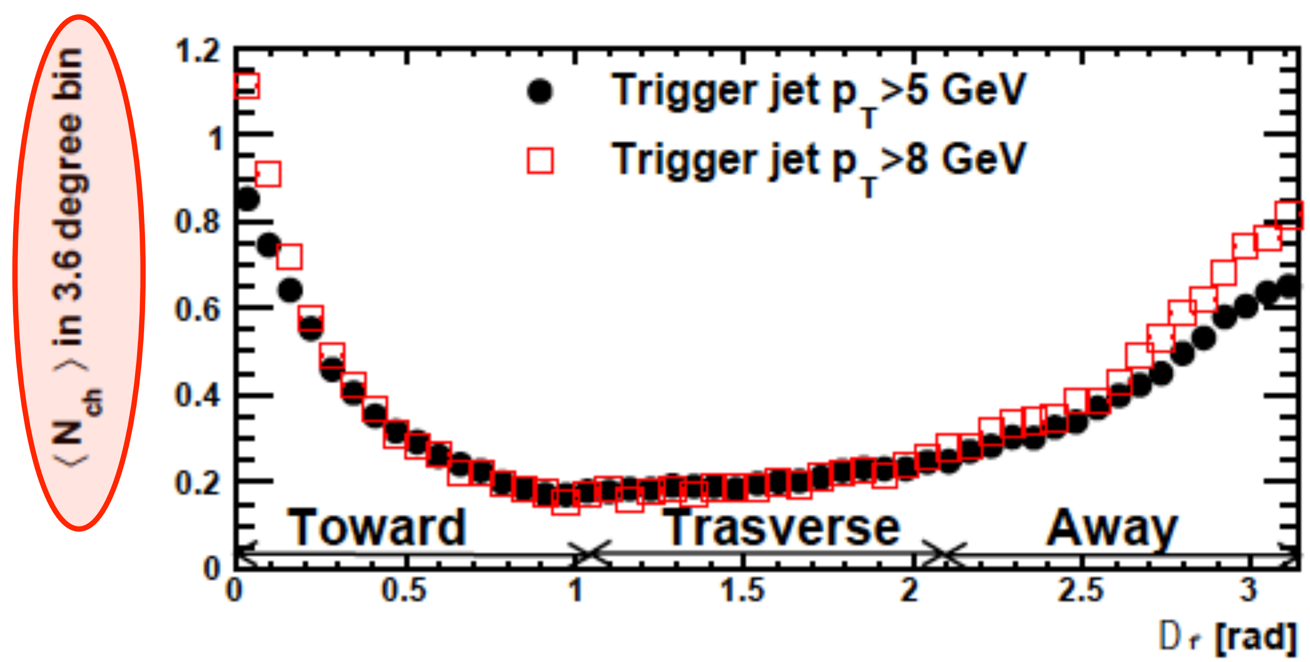
‘High Multiplicity’ events at EIC







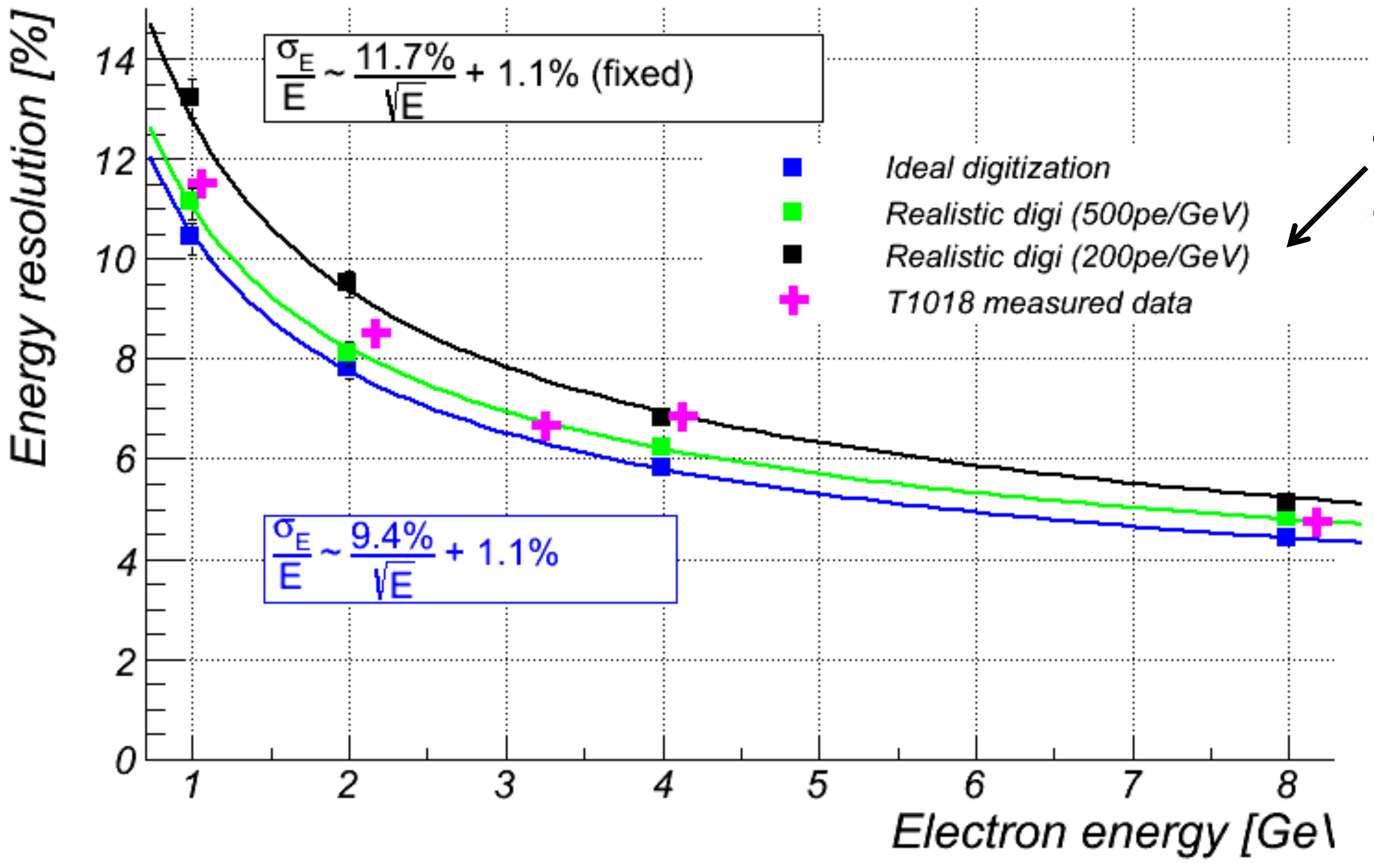




- E.C. Aschenauer et.al. “The Electron – Ion Collider Assessing the energy dependence of Key Measurements” arXiv:1708.01527v3
- B.Page, Santa Fe, Jets and Heavy Flavor Workshop, Jan 29, 2018

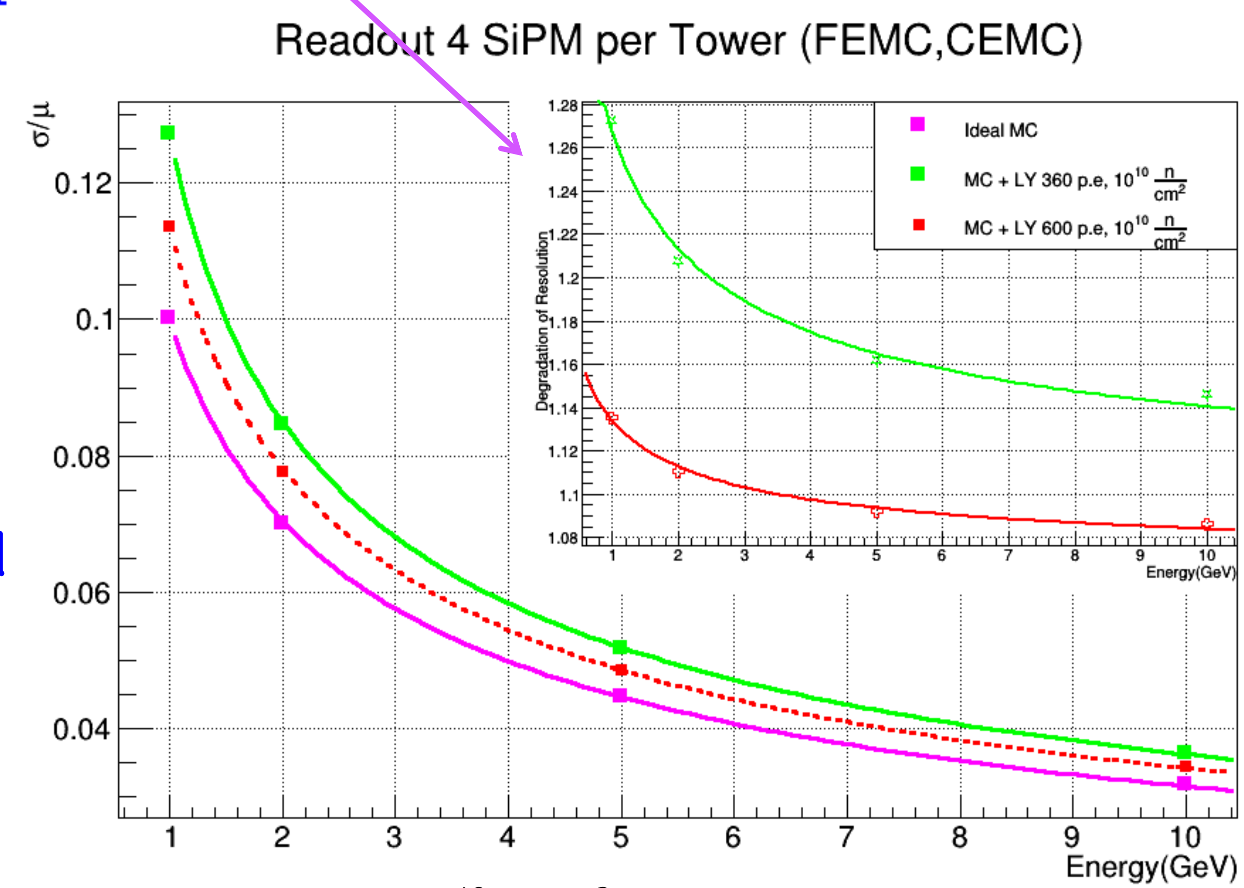
Jets are soft, occupancy and rates are low.

Energy Resolution, Light Yield, Noise and Granularity



FEMC energy resolution study (A.Kiselev 2013)

- **200 p.e./GeV is enough, but…**
- But there are SiPMs damages as we measured in 2015, 2016, 2017 at STAR IP (EIC conditions), resulting in degradation of energy resolution (single particle)



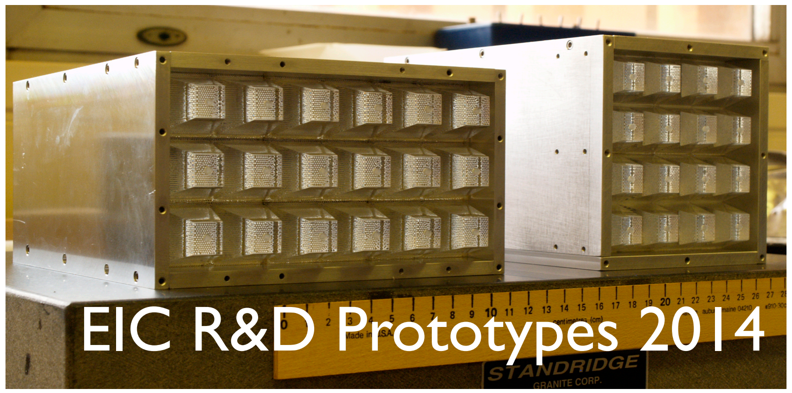
Neutron fluence 10^{10} n/cm^2. Cluster 3 x3 Eq. noise ~ 60 MeV

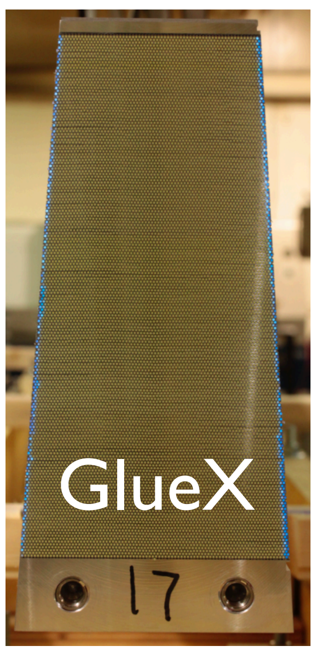
For Jets

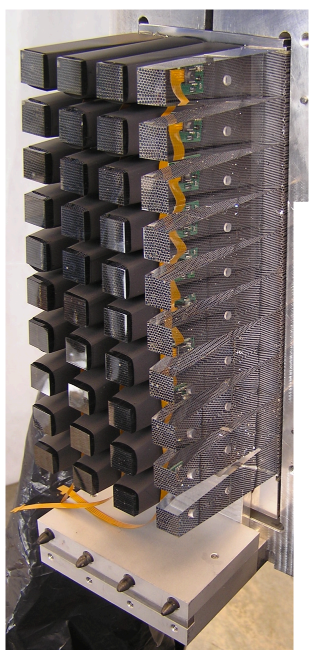
- Assume granularity similar to what was used in prototypes or in the sPHENIX EMCal.
- Jet Patch (R=1) spans across ~ 7500 towers.
- Eq. Noise due to degradation of SiPMs – 1.7 GeV/Jet Patch.

With appropriate choice of readout both problems may be irrelevant.

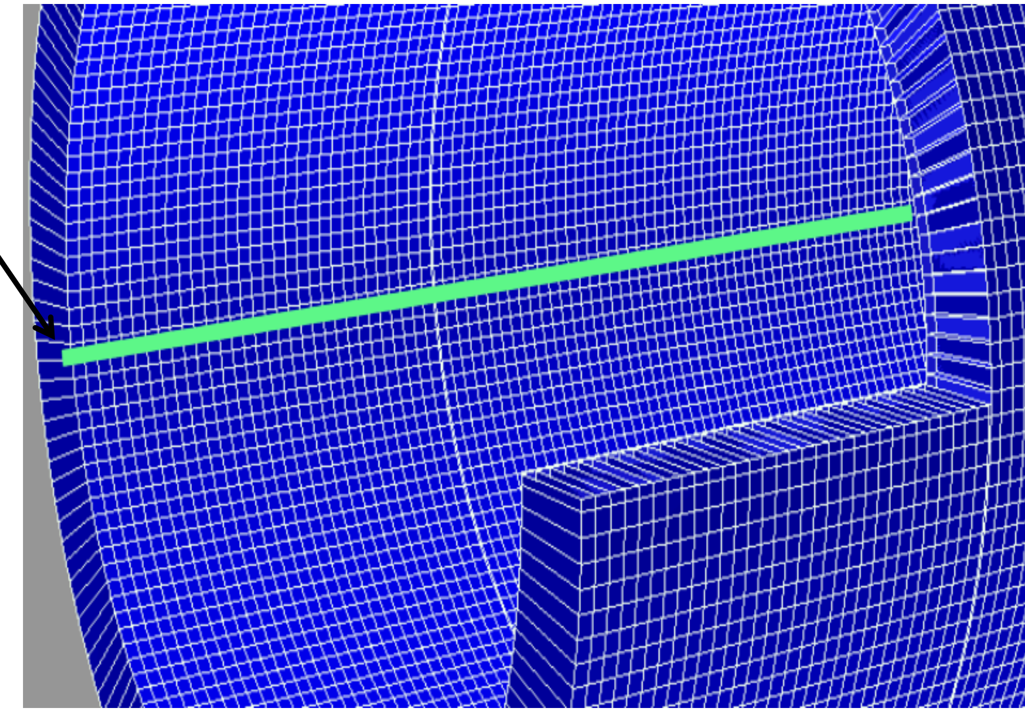
- Excessive granularity is result of combination of SiPMs with compact light light guides.
- Not required for Barrel Calorimeter.
- Propose to investigate alternative readout scheme (conceptually KLOE, GlueX).







- A single WLS collects light from string of tower.
- Readout from both ends (6 + 6 SiPMs).
- Seamless Detector
- Seamless Readout
- Mechanically Decoupled.
- Phi granularity ~ 1 deg. may be sufficient (easy to change).



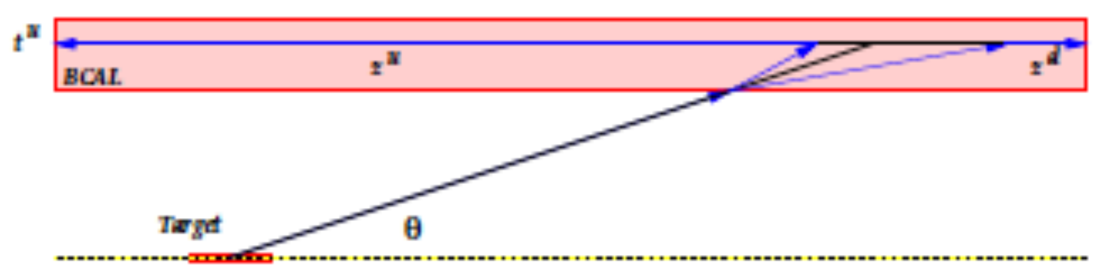
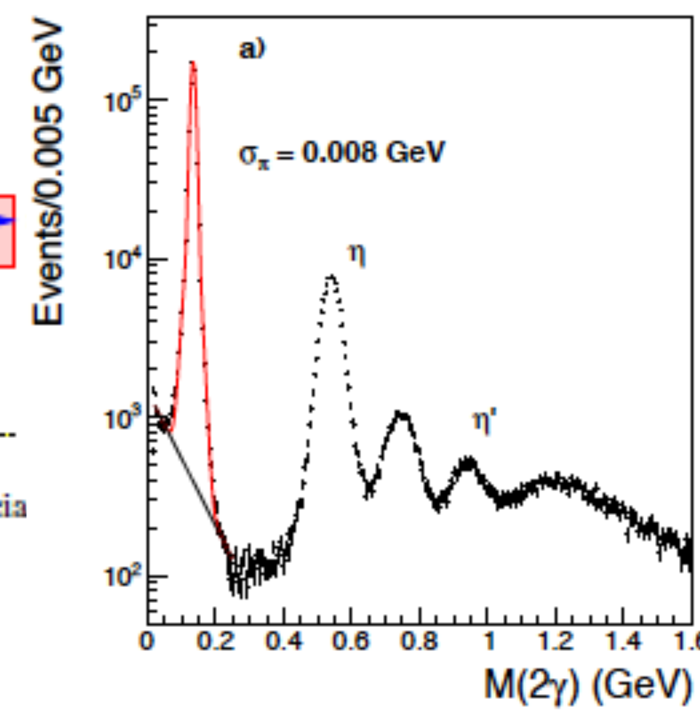


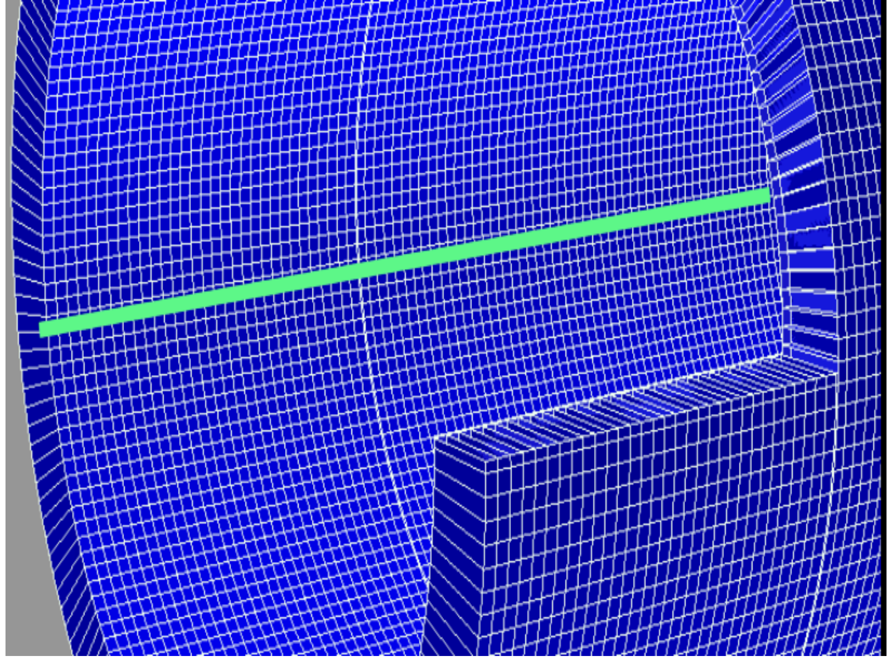
Figure 17: Toy model of the shower development inside the BCAL and associa signals.

GlueX NIM A896 (2018) 24-42



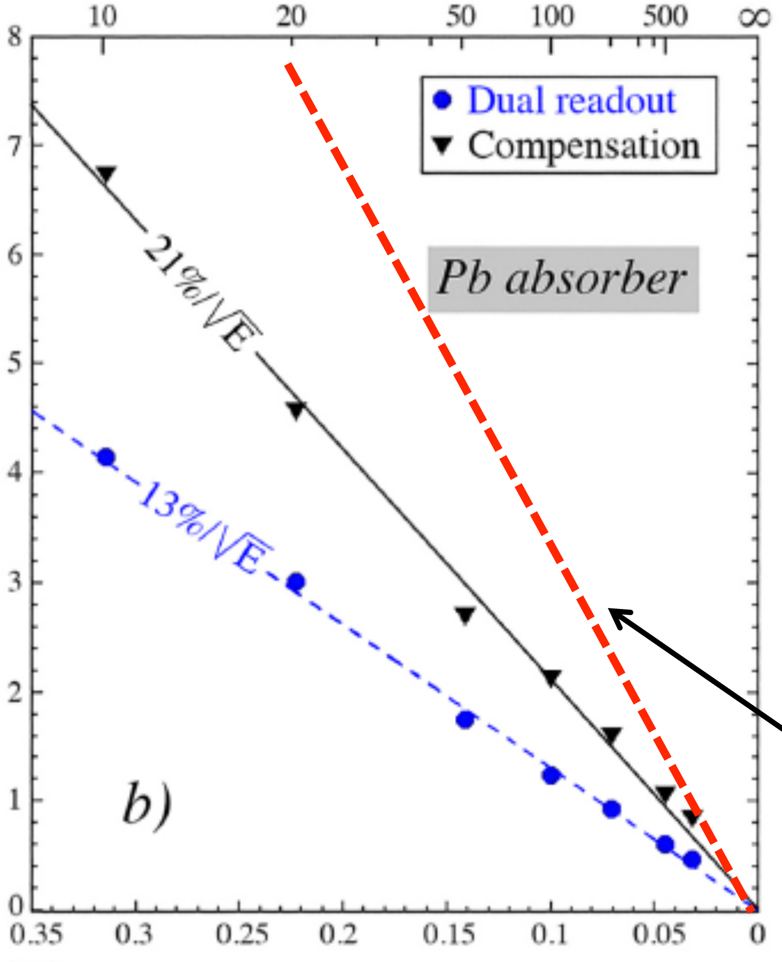
Back-of-the-envelope calculations shows that LY may be close to what we have now with light guides, uniformity should be automatically much better. (WLS trapping efficiency 18% , PDE for 50 or 75 um sensors is about 50% higher than for one we used in 2014.)

Practical considerations:

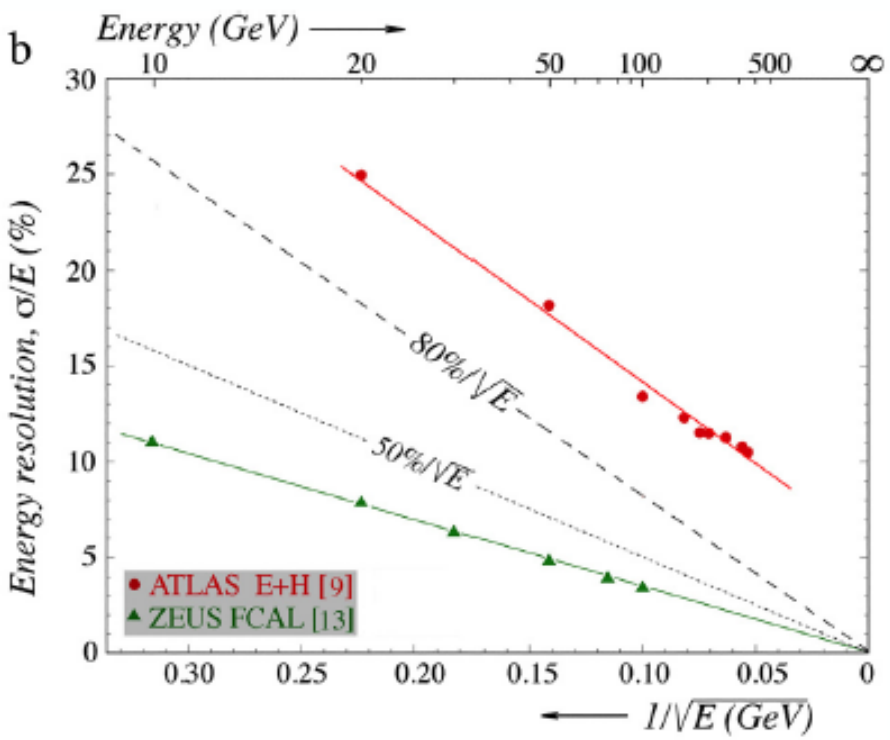


- Reduction of readout channels by factor 150-200.
- Reduction of photo detectors by factor of 80 (reduction of the excess noise in the detector due to degradation of SiPMs with exposure).
- Good uniformity of light collection.
- Simplicity in calibration and monitoring.
- 'Mixed light' collection scheme, which is not sensitive to differential degradation of SiPMs under irradiation (constant term in energy resolution).
- Simple, mechanically independent readout and W/ScFi structure itself.
- Absence of active components inside the magnet, which require cooling/repairs etc.
- Ease of maintenance during long-term operation.
- Barrel calorimeter can be made completely gapless (as shown), self supporting and it can be very thin saving space in a superconducting magnet for tracking and PID.

Test Run 2019, piggyback on STAR test run. Modify existing Forward EMcal for WLS readout.
Measure LY, Energy resolution, Uniformity of response.



ATLAS Calorimeter



Plots from
S.Lee, M.Livan, R.Wigmans
CALOR 2018

General comments for high resolution HCals.

- For EIC requirements for central detector – evolving.
- For ZDC record type resolution (C/S, Proposal not funded)
- No developments since 2014 (STAR Forward, EIC)
  Compensated W/ScFi EM+ Pb/Sc HCal
  Resolution ~ 60%/sqrt(E) +5.6% .
- Practical limitations important! (SPACAL as an example)

Record holder. 20t, full absorption. Only Test beam results with all hardware tricks available at that time. It is about 50% off from theoretical limit.

Limitations at EIC:

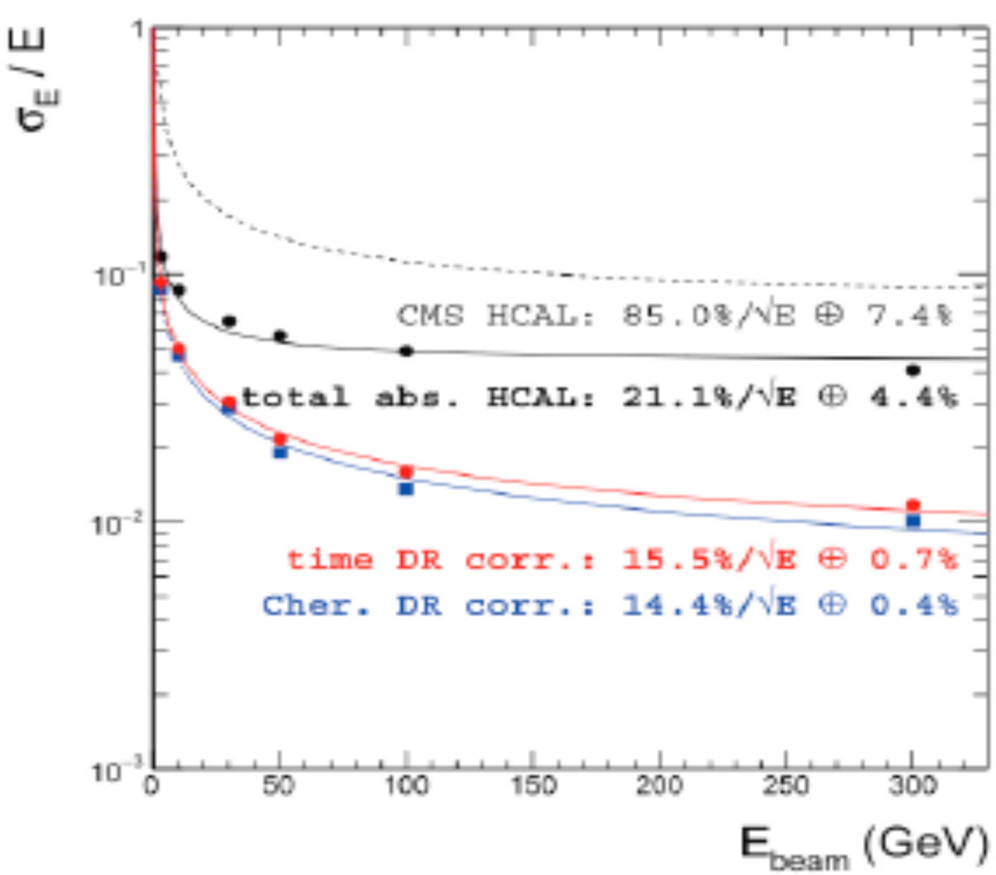
- Central detector – Space, EMcal up-front, structural elements in between.
- ZDC – transverse size, integrated beam pipe, rate.
- For practical reasons good to have ENDcap made of steel.

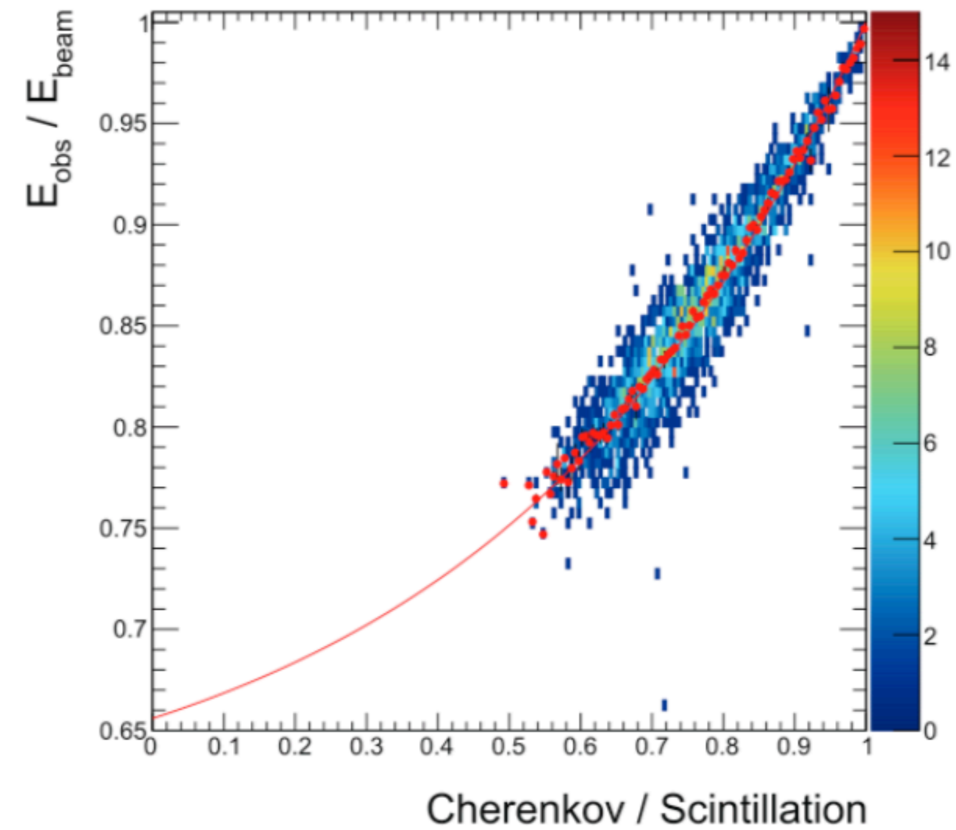
Dual Readout methods for high resolution HCals.

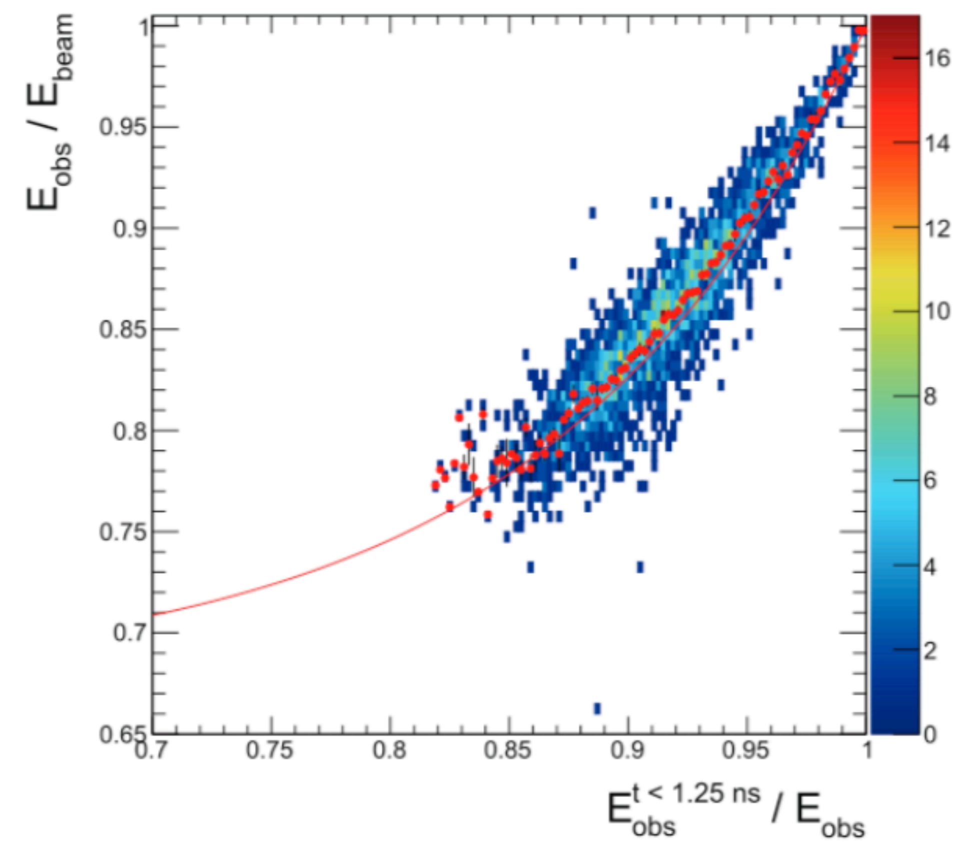
Concept

- Usually (absorber dependent), number of neutrons released in shower is correlated with 'invisible' energy (~40% in hadronic showers).
- Find observable which correlate with number of neutrons (C/S, Time, Spatial characteristics of shower).
- E-by-E correct detected energy using this observable.

Theoretically, believed, hadron resolution can be very good (below 20%/√E, small constant term, good linearity).

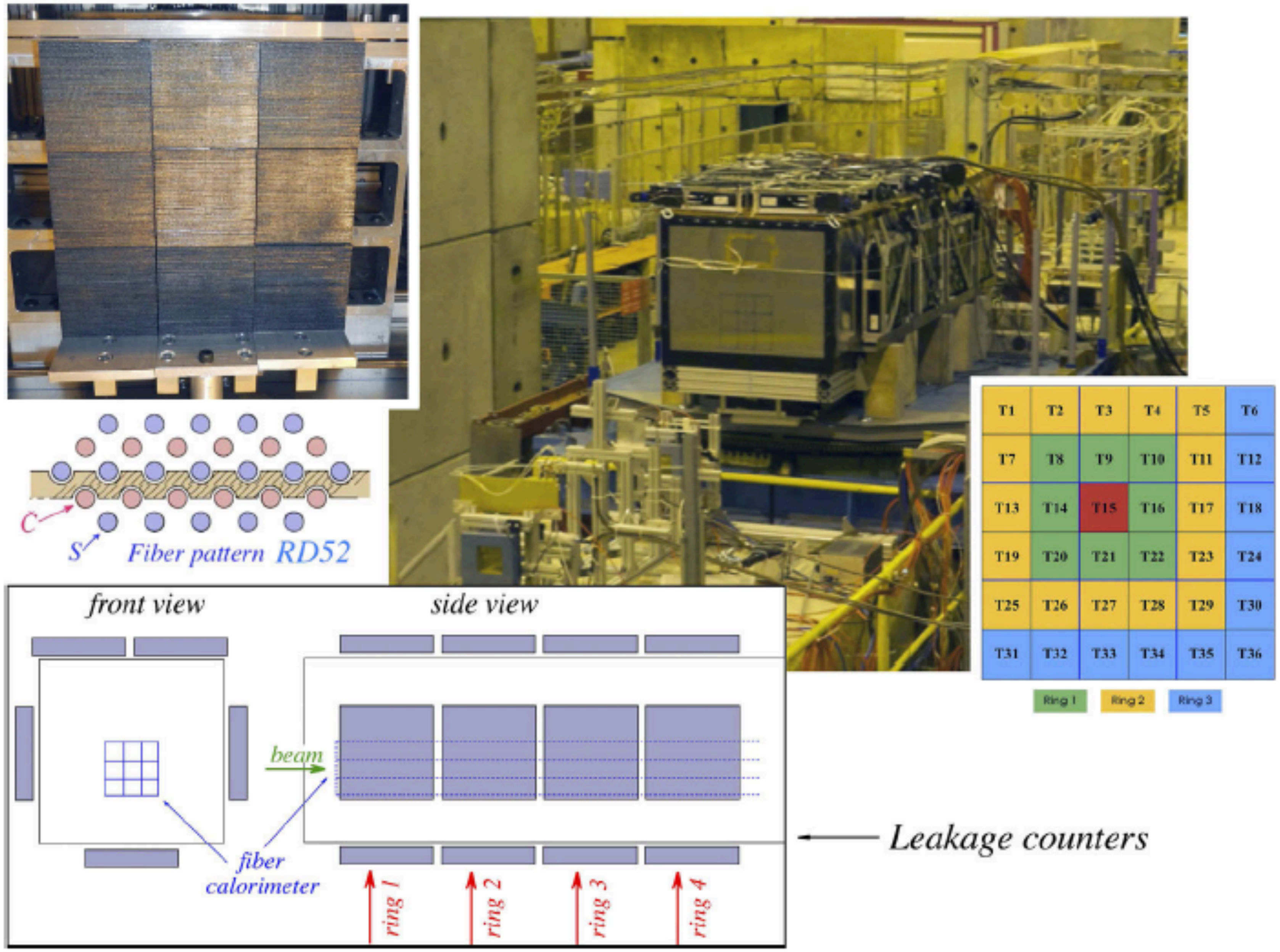






A. Bengalia et.al. IEEE Trans. Nucl. Sci. V63, N2, 2016

High resolution Hcals are challenging.



Rev.Mod.Phys.,Vol 90, No. 2, 2018

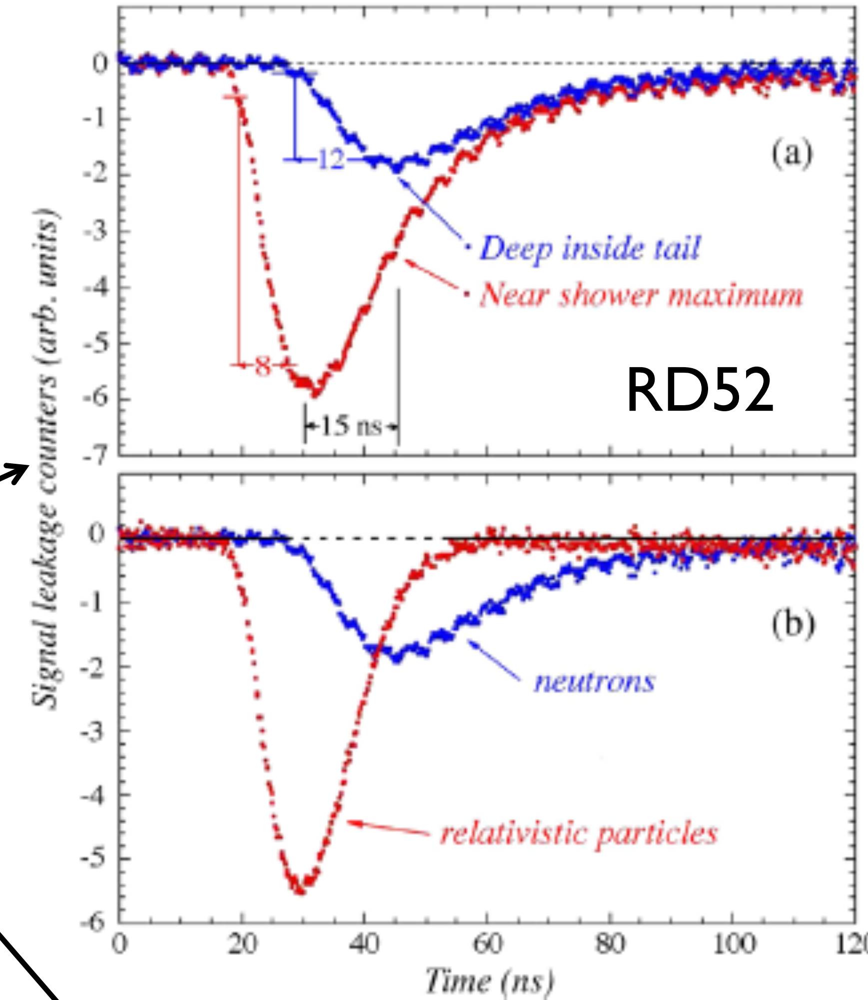
- 15 years of the development of DREAM, RD52. Still no 100% proof it will deliver.
- Size of the detector, practical limitations with S/C method.
- Good thing, it spurred discussions and other approaches started to emerge.
- Now some people think timing will be easier to implement in practice.
- There were no other experimental investigations for dual readout techniques than DREAM, RD52

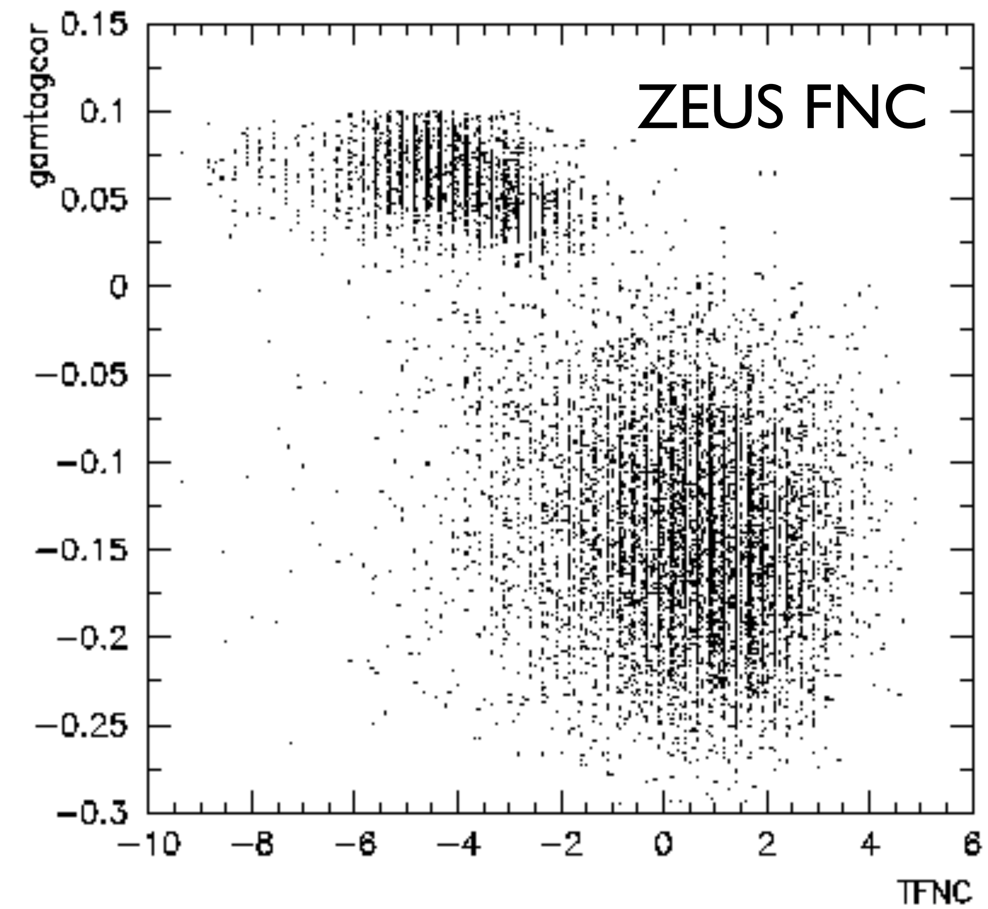
What is in the proposal.

- Investigate if dual readout method will work for Tile/WLS type structures (method of construction we developed for 2014 HCAL prototype).
- Direct proof is out of reach due to size of the detector.
- Most likely we will end up (if it will work) with something similar measured by RD52 (fibers faster than Tiles/WLS).
- ZEUS FNC Tile/WLS method worked out by W. Schmidtke to use timing for e/h separation, i.e. timing is not hopeless for such structures, he joined our efforts now.
- Next year gives us opportunity to do such thing utilizing components from 'Cold QCD forward calorimeter, which is being constructed now (absorber tiles Fe, Pb, scintillating tiles).
- A. Kiselev, will run optimization, what can be built from this components to get 'proof of principle'. He also arranged 5Gs/s DAQ for the test run.

If method will work future steps are:

- MC optimization of ZDC.
- MC optimization of EndCap.
- Pursue LDRD to build ZDC and get final proof with testing it at FNAL.





Budget Scenario	100%	20% cut	40% cut
UCLA support for students (26% overhead included)	$10.08k	$10.08k	$10.08k
Travel (26 % overhead included)	$12.6k	$12.6k	$12.6k
W/ScFi with WLS readout	$10k	0	0
HCAL WLS	$6k	$6k	$6k
HCAL Mechanical Components	$3k	$3k	$3k
HCAL Machine Shop (26% overhed included)	$9.5 k	$9.5k	$9.5k
HCAL PMTs	$15k	$15k	0
Total	**$66.18k**	**$56.18k**	**$41.18k**